

# IEEE P802.15 Working Group for Wireless Personal Area Networks

## WPAN Coexistence Performance Evaluation: MAC Simulation Environment and Preliminary Results

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NIST

## Outline

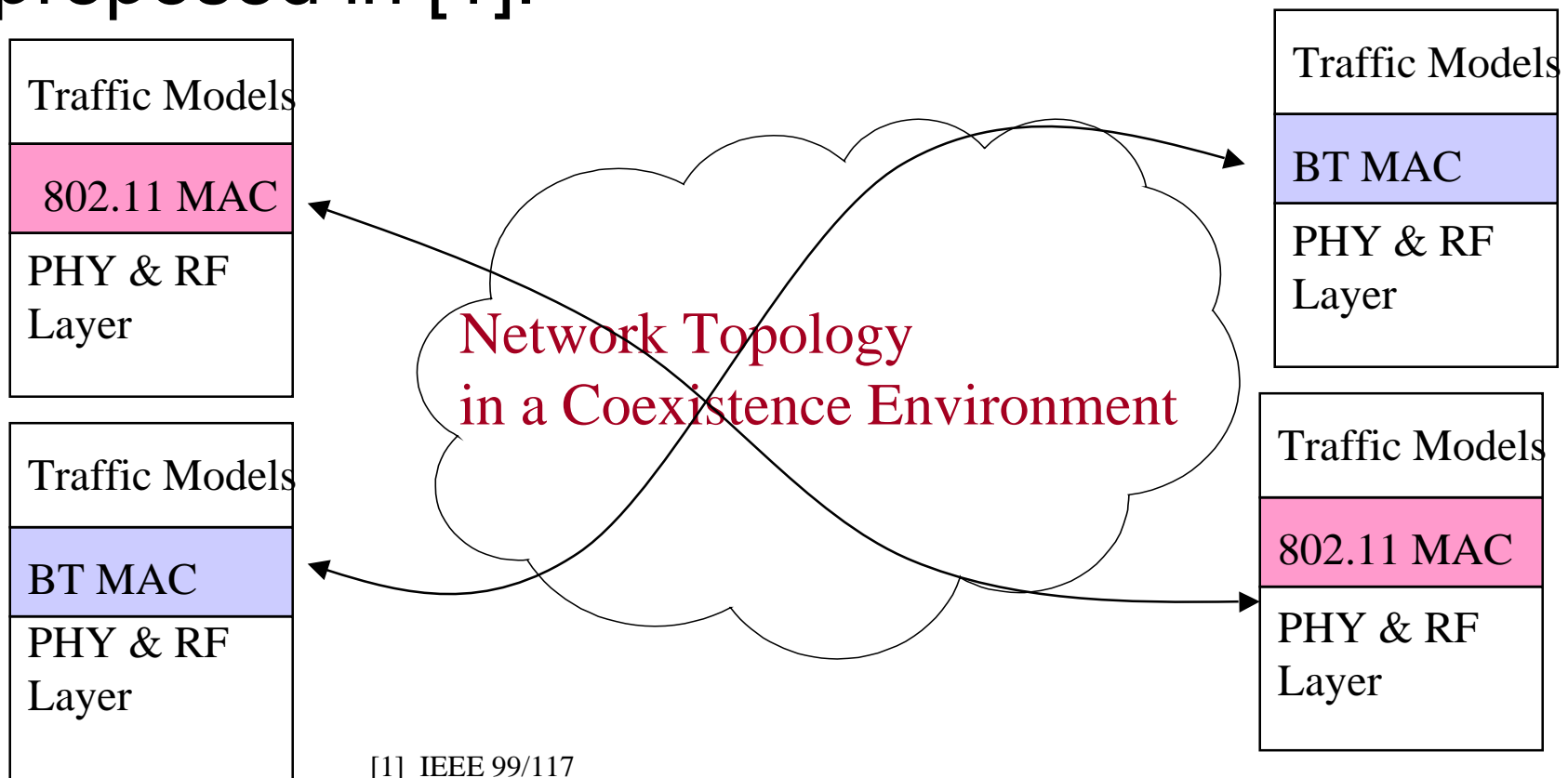
- MAC coexistence evaluation platform
- Part I: Simulation Environment
  - Traffic model
  - MAC model
  - PHY and RF assumptions
- Part II: Preliminary Results
  - Sanity check
  - Bluetooth reference scenario: LAN Access

## MAC Coexistence Evaluation Platform

- Explore different models for the MAC layer coexistence performance evaluation platform.
- *Invariant:* performance results are collected at the MAC layer based on PHY, RF models and assumptions.

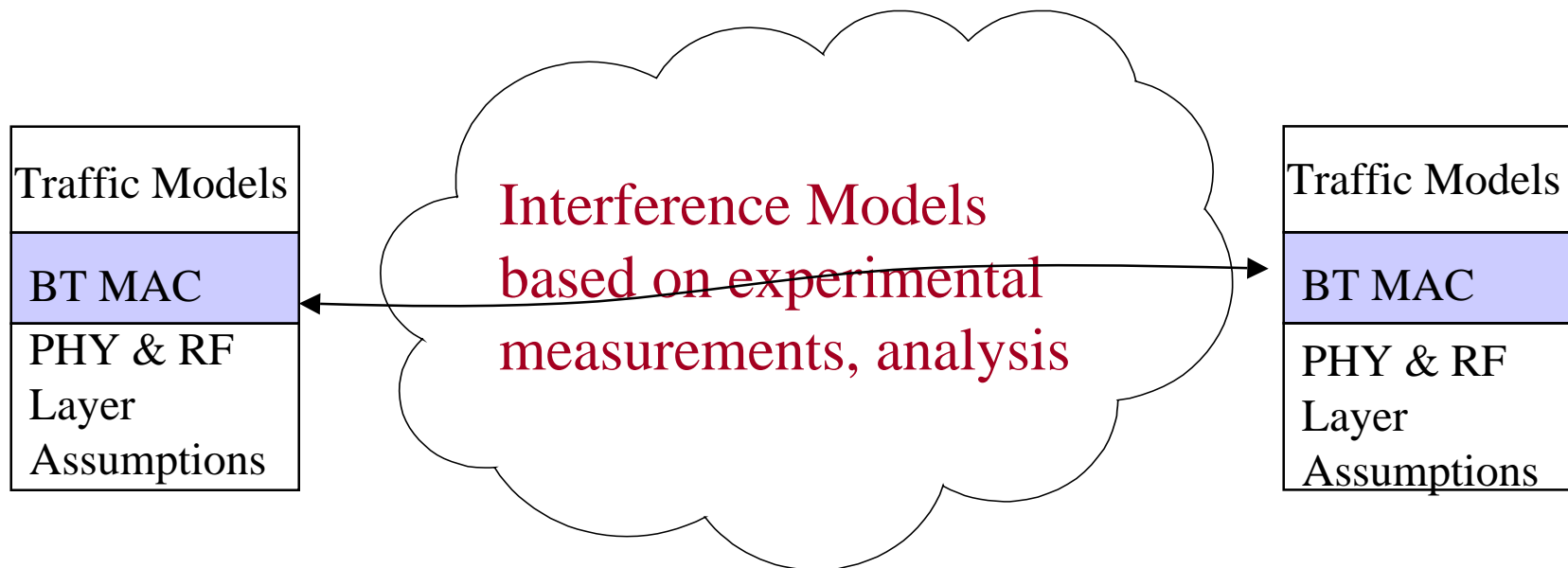
## MAC Coexistence: Model I

- Heterogeneous set-up where BT and 802.11 are co-located within the same environment as proposed in [1].



## MAC Coexistence: Model II

- Homogeneous set-up where different devices (BT or 802.11) are considered separately with respect to (accurate) interference models.\*



\* IEEE 802.15-99/98r0

# Simulation Environment

## Traffic Models: LAN Access

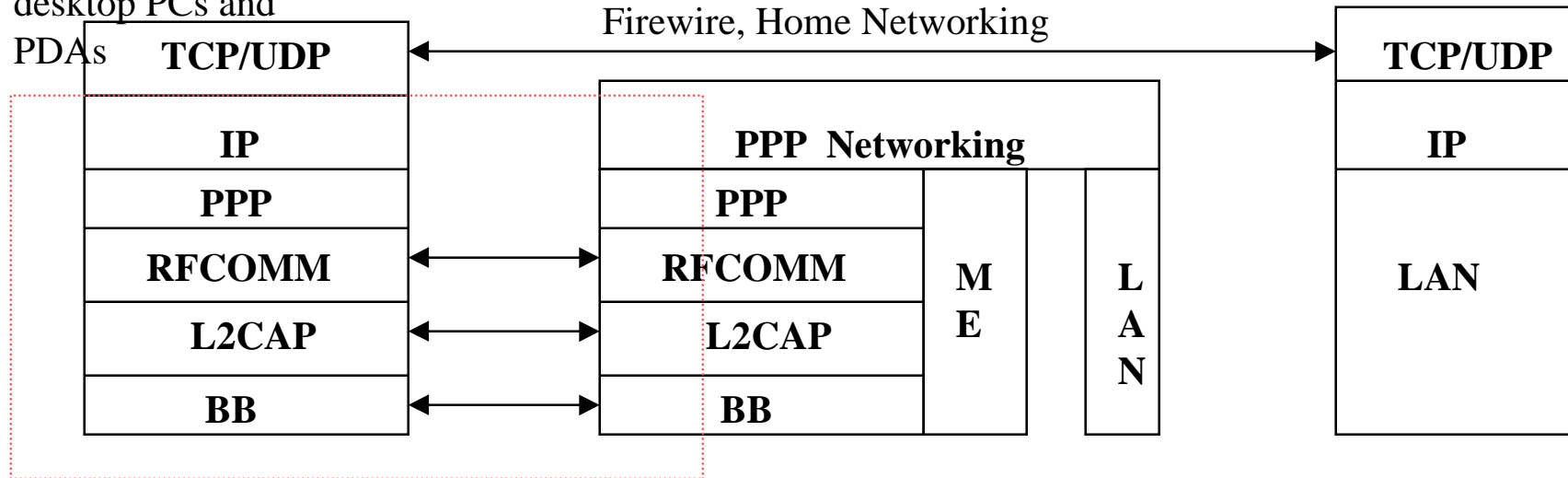
- LAN Access Profile, Bluetooth Spec. V1.0B
- PPP connection with LAP in order to gain access to a LAN.

### Data Terminal:

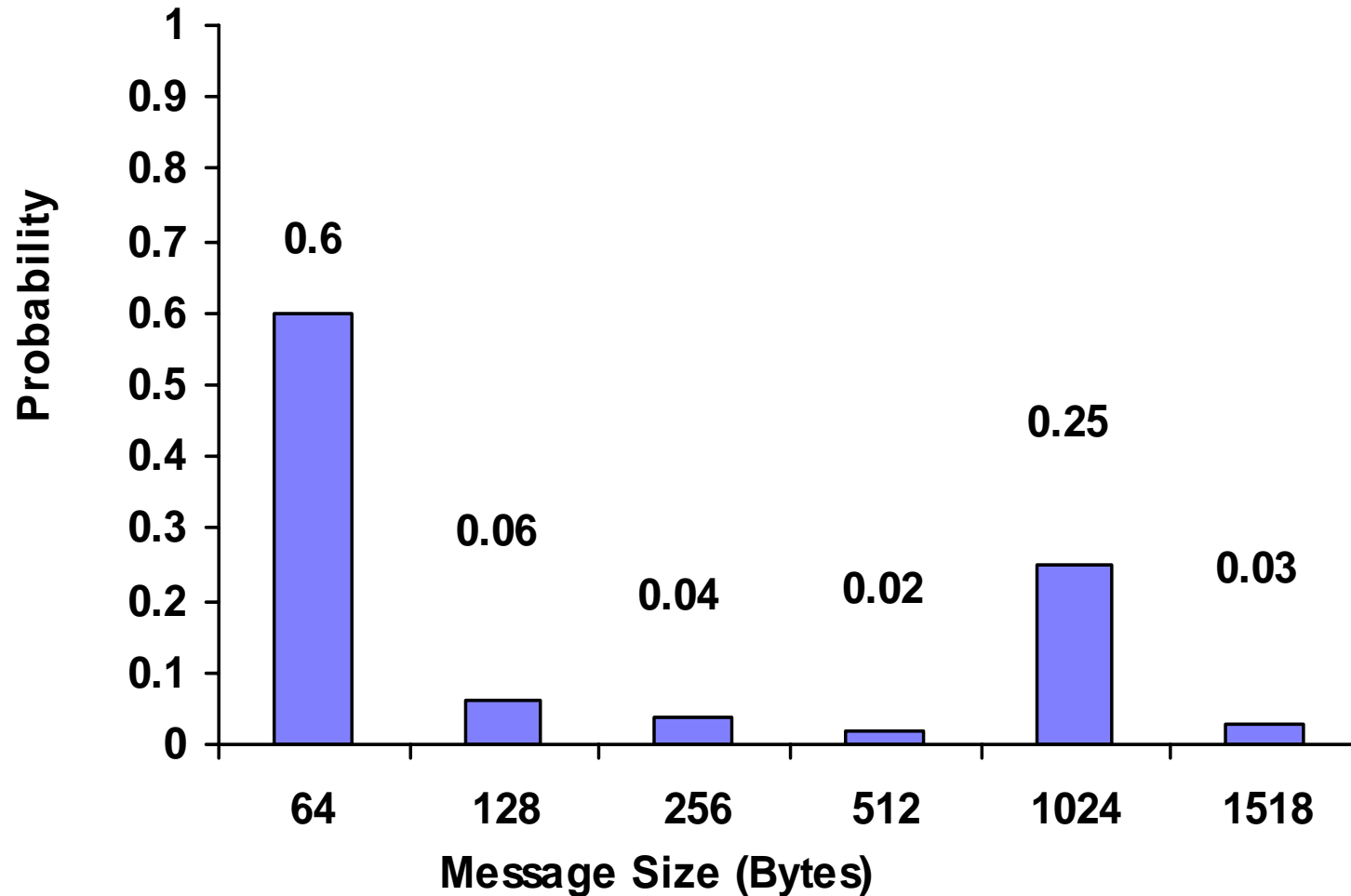
Laptops, Notebooks,  
desktop PCs and  
PDAs

### LAN Access Point:

Ethernet, Token Ring, Fiber  
Channel, Cable Modems,  
Firewire, Home Networking



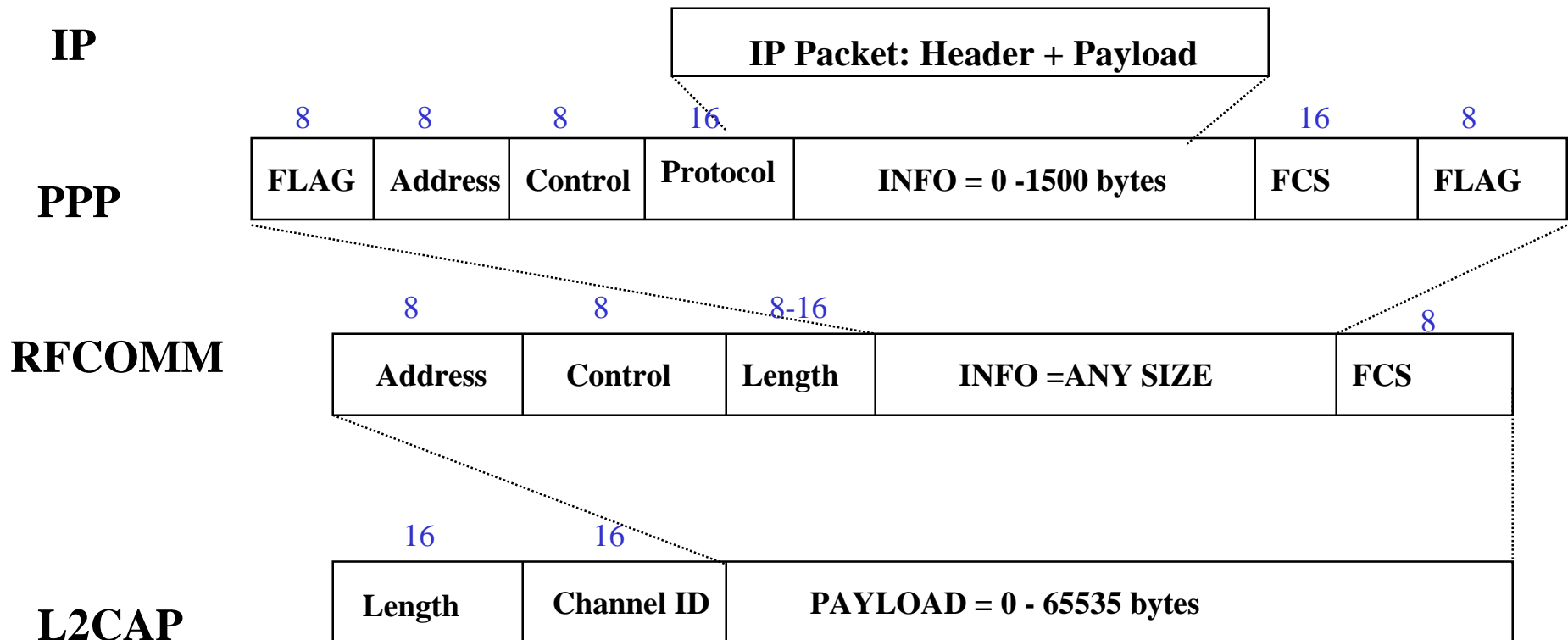
# Traffic Distribution: IP Packet Generation



\* IEEE 802.14/96-083r2



# Packet Encapsulation

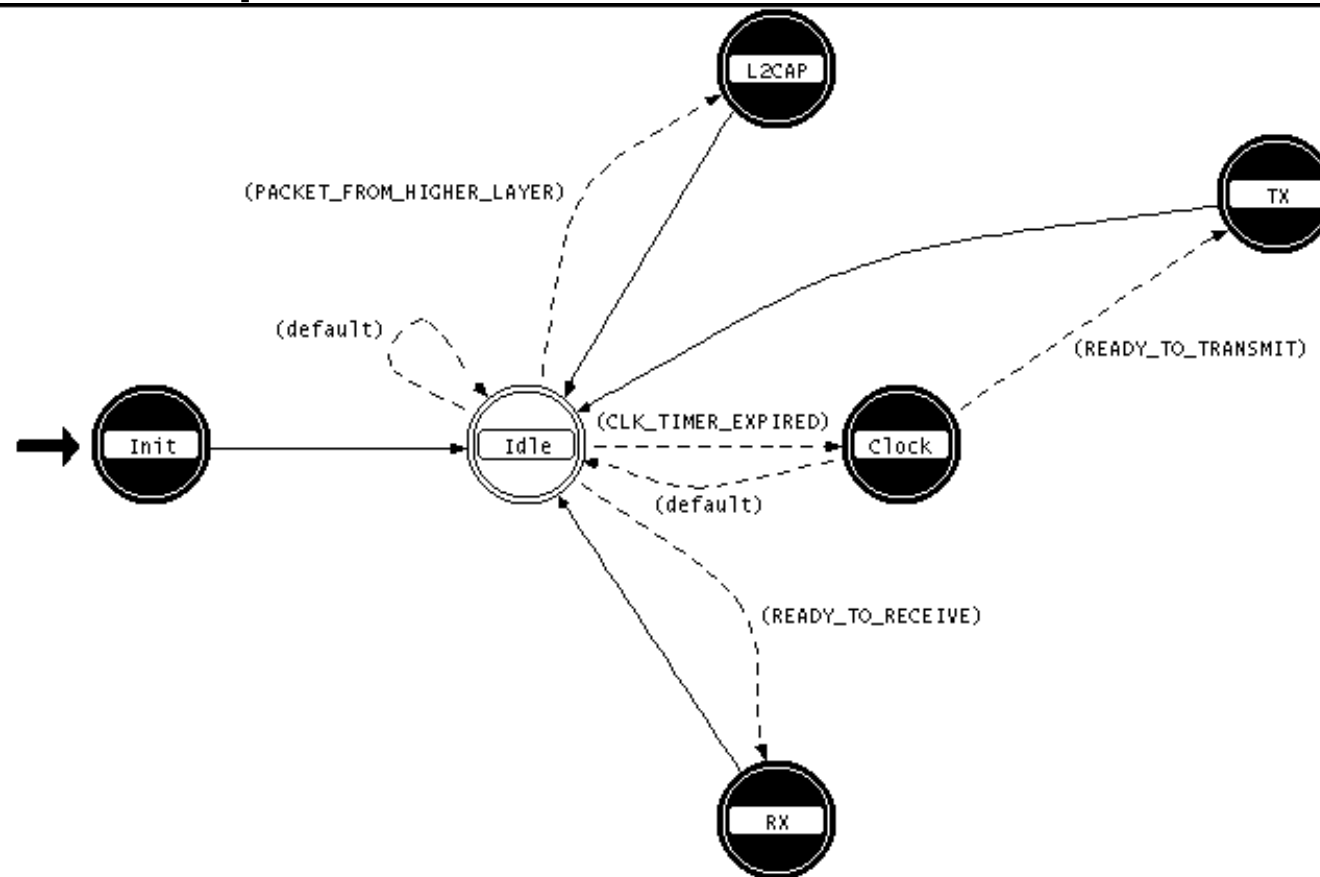


# Baseband Segmentation

**L2CAP****DM3****DM5****Baseband**

# MAC Model

- Developed a BT MAC device in OPNET\*.



\*OPNET is a Trademark of OPNET Technologies Inc.

## MAC Model Assumptions

- Connection mode (no page scan or inquiry)
- Master / Slave models
- Round Robin master transmission scheduler
- Asynchronous Connection Less (ACL) Link
- Frequency Hopping

## Future Extensions

- Synchronous Connection Oriented (SCO) Link
- master scheduler
- broadcast; L2CAP (?); LMP (?)

## TX Model Attributes\*

| Attribute       | Value         |
|-----------------|---------------|
| modulation      | bpsk          |
| rxgroup model   | bt_ma_rxgroup |
| txdel model     | dra_txdel     |
| closure model   | dra_closure   |
| chanmatch model | bt_chanmatch  |
| tagain model    | dra_tagain    |
| propdel model   | dra_propdel   |

\* OPNET Transmitter model attributes  
Submission

## TX Parameters

- Transmission+Propagation delay: computes the time required to transmit a packet until it reaches its destination.
- Closure: determines if a signal can reach a destination and allows dynamic enabling and disabling of links.
- Channel match: classifies the transmission as valid, noise, ignore based on frequency, bandwidth, data rate, spreading code etc.
- Transmitter antenna gain: computes transmitter antenna gain in the direction of the receiver.

## RX Model Attributes\*

|                |              |
|----------------|--------------|
| modulation     | bpsk         |
| noise figure   | 1.0          |
| ecc threshold  | 0.0          |
| ragain model   | dra_ragain   |
| power model    | dra_power    |
| bkgnoise model | dra_bkgnoise |
| inoise model   | dra_inoise   |
| snr model      | dra_snr      |
| ber model      | dra_ber      |
| error model    | dra_error    |
| ecc model      | dra_ecc      |

\* OPNET Receiver model attributes  
Submission

## RX Parameters

- Noise figure: effect of thermal noise on radio transmission.
- Ecc threshold/model: Percentage of bit errors allowed in a packet (err/bit).
- Power model: computes the received power level for an incoming transmission.
- Background noise/ Inoise: computes the background/ interference noise affecting incoming radio transmissions.
- SNR/ber models: computes signal-to-noise ratio and expected bit error rates.



## RX Statistics

- BER: bit error rate for the packet arriving at the receiving channel.
- Packet loss ratio: boolean value corresponding to the acceptance/rejection of packets.
- Power: average power of packet arriving at the receiver channel.
- Signal/noise ratio: ratio of the average power of a packet received and the combined average power of interference sources.

# Channel Attributes\*

(channel) Table

| data rate (bp | packet format | bandwidth (kH | min frequency | spreading cod | power (W) |
|---------------|---------------|---------------|---------------|---------------|-----------|
| 1,000,000     | all formatted | 83,500        | 2,402         | disabled      | 0.1       |

1

Rows

View Row Count Properties

Details

Promote

Delete

Cancel

OK

(channel) Table

| data rate (bp | packet format | bandwidth (kH | min frequency | spreading cod | processing ga |
|---------------|---------------|---------------|---------------|---------------|---------------|
| 1,000,000     | all formatted | 83,500        | 2,402         | disabled      | channel bw/dr |

1

Rows

View Row Count Properties

Details

Promote

Delete

Cancel

OK

\* OPNET Channel attributes

Submission

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# Preliminary Results

## Sanity Check

- Number of devices in a piconet:  
2 devices (Master/ Slave).
- Distance between devices: 10m
- Traffic: DM5 packets symmetric master/slave communication, exponential distribution for packet interarrival rate.
- Baseband packet size is:

$$72 + 54 + (224 + 2 + 2) * 8 + \text{FEC} = 2871 \text{ bits}$$



Access

Header

payload

DM5 Header

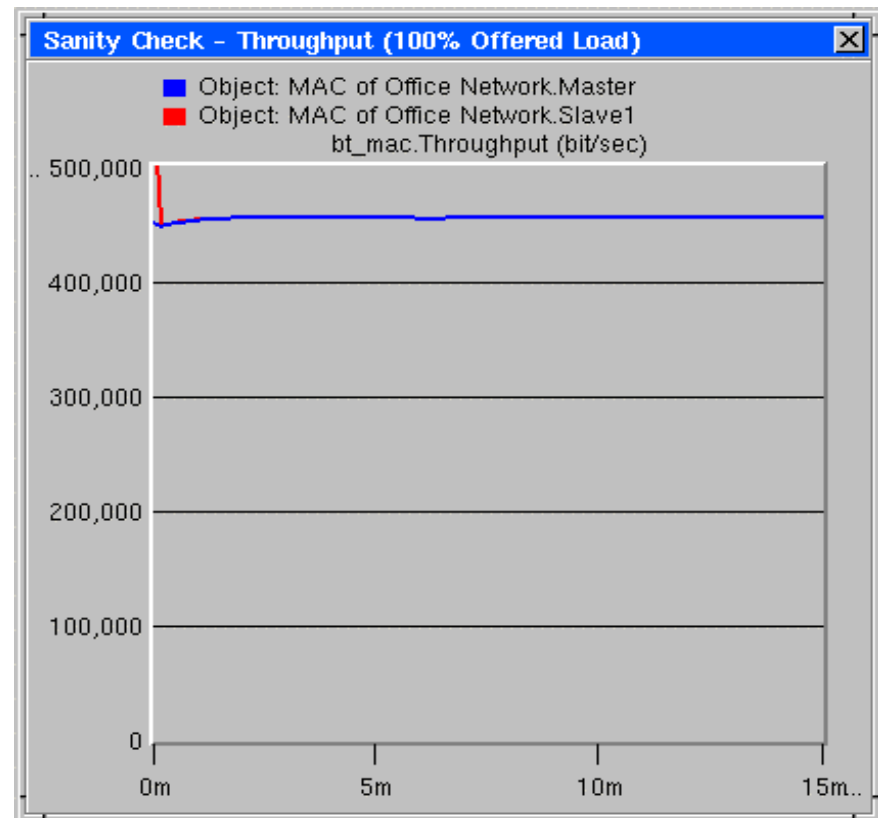
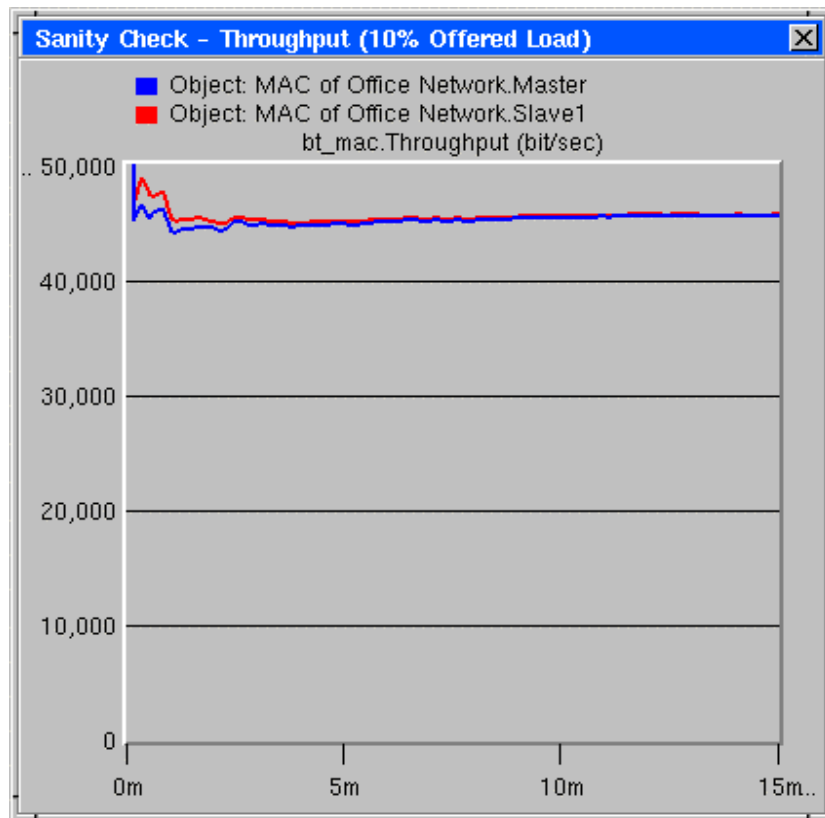
CRC

6 + 915

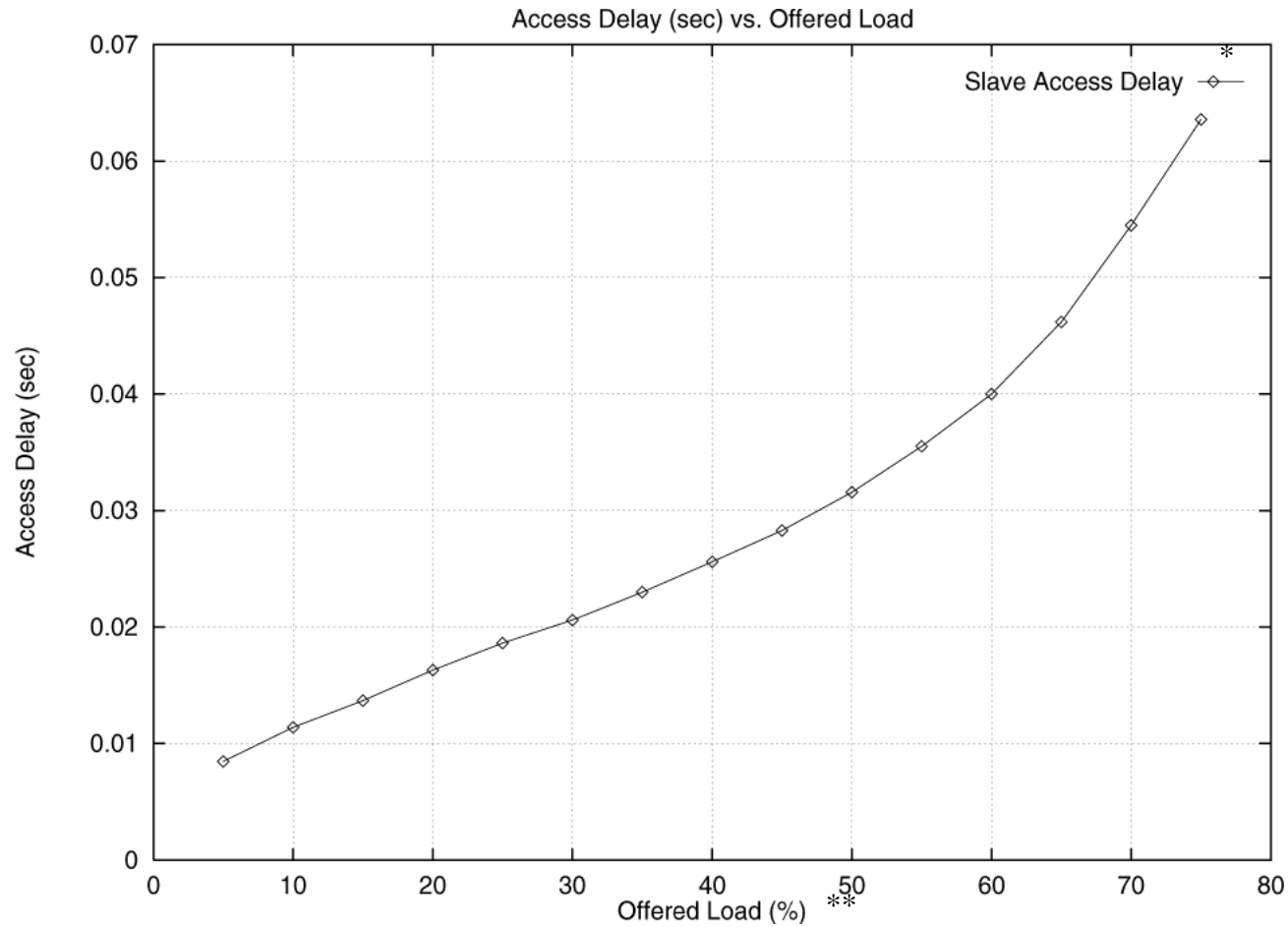
## Sanity Check (cont.)

- Maximum bit rate per device (including headers, CRC, FEC overhead) is:  
$$2871 / (5 * 625 * 2) = 0.45936 \text{ Mbits/s}$$
- Minimum access delay (master) at low offered load (no packet waiting in buffer) is:  
$$5 \text{ (slots)} * 625 \text{ (us)} = 3.125 \text{ ms}$$
- Maximum access delay (master) at low offered load (no packet waiting in buffer) is:  
$$15 \text{ (slots)} * 625 \text{ (us)} = 9.375 \text{ ms}$$

# Sanity Check Results: Throughput



# Sanity Check Results: Access Delay



Note: \*\* Access delays are collected at the slave corresponding to the master traffic access delay.

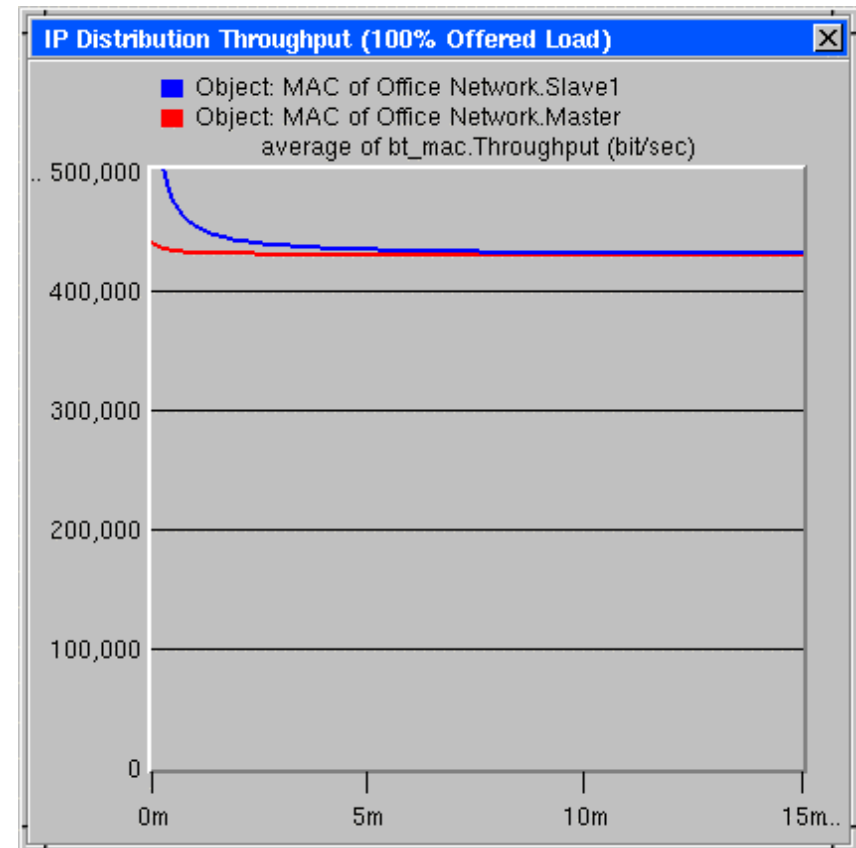
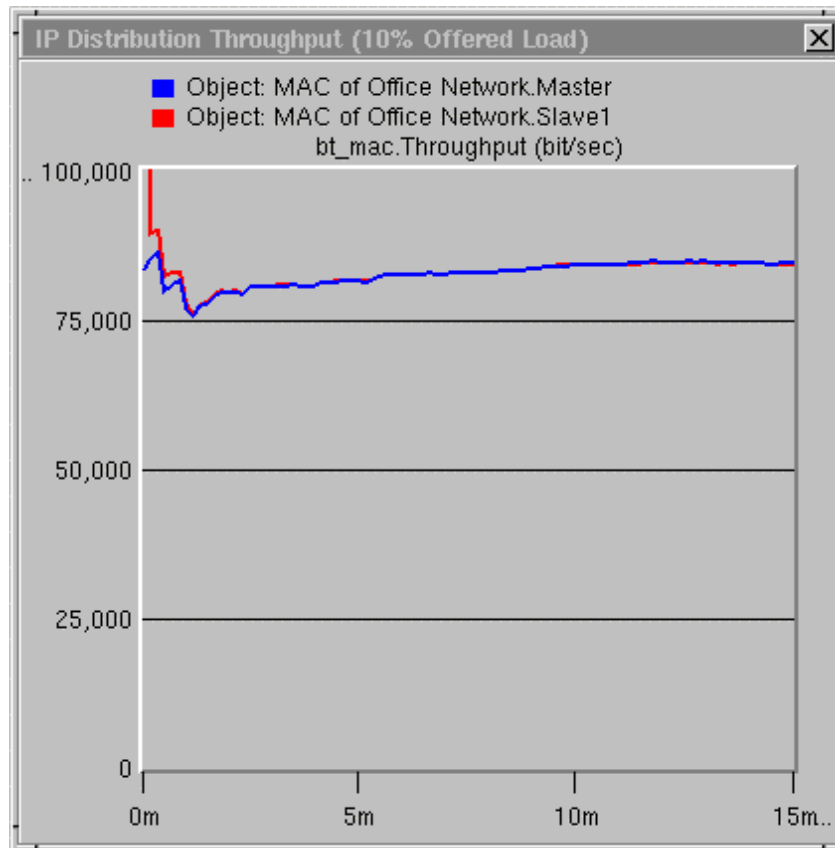
\*\* Offered load is a percentage of the total channel capacity in both directions

## LAN Access Scenario

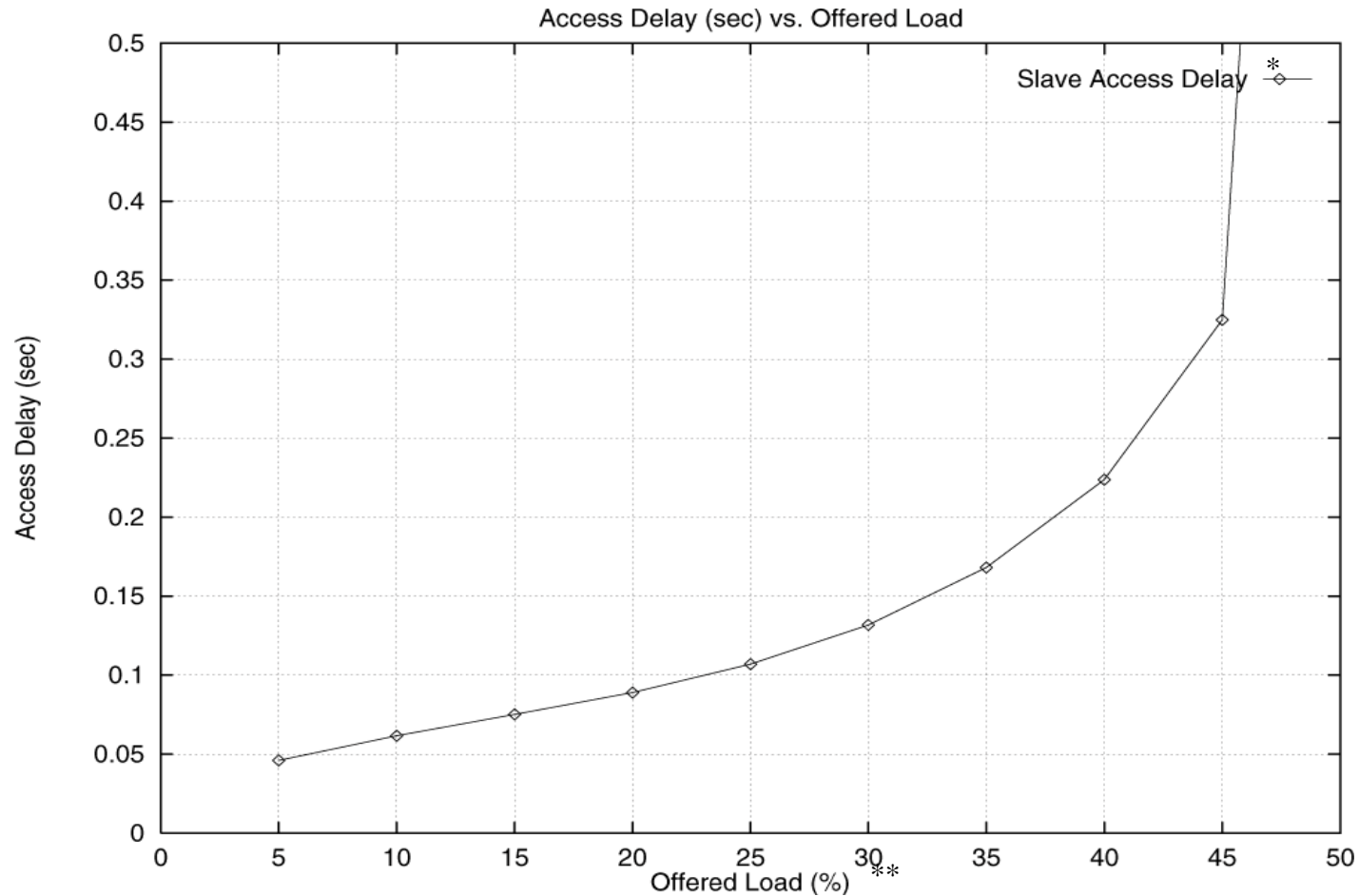
- Number of devices in a piconet:  
2 devices (Master/ Slave).
- Distance between devices: 10m
- Traffic: LAN Access (IP traffic distribution)
- Average packet size is: 385.1 bytes  
1 DM5 (224 bytes) + 1 DM5 (162 bytes) = 4992 bits
- Maximum bit rate per device (including headers, CRC, FEC overhead) is:  
 $4992 / (10 * 625 * 2) = 0.39936 \text{ Mbits/s}$



# LAN Access Results: Throughput



# LAN Access Results: Access Delay



Note: \*\* Access delays are collected at the slave corresponding to the master traffic access delay.

\*\* Offered load is a percentage of the total channel capacity in both directions

## Summary

- Presented a status report on the BT MAC model development.
- Preliminary results:
  - sanity check
  - BT reference scenario

## Next Step

- Results:
  - WLAN reference scenario
  - Heterogeneous scenario with 2 WLAN devices and 2 BT devices.
- Continue the development of the BT MAC model.
- Extend the PHY and RF models
- Several scenarios to look at with different traffic types, number of devices, configurations.